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.. not available for a specific reference period
... not applicable
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0^s value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p} preliminary
^{r} revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E} use with caution
F too unreliable to be published
* significantly different from reference category ($p < 0.05$)

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Parent-Child association in body weight status

by Tracey Bushnik, Didier Garriguet and Rachel Colley

Abstract:

Background: The prevalence of overweight and obesity among children and adults has risen in Canada. Studies suggest that parent obesity is a risk factor for overweight and obesity in children. This analysis examines associations between biological parent and child body mass index (BMI) in a nationally representative sample of Canadian children.

Methods: The analysis is based on data collected for 1,563 children aged 6 to 10 in the first three cycles of the Canadian Health Measures Survey (2007 to 2013). BMI was calculated using measured height and weight. Pearson correlation, logistic, and linear regression analyses examined associations between biological parent and child BMI and obesity status, controlling for other risk factors.

Results: Biological parent and child BMI were correlated. When risk factors were taken into account, a child's average BMI increased as their parent's BMI increased. Parent BMI explained 2% of the variance in boys' BMI and 12% of the variance in girls' BMI. Boys and girls with a biological parent who was obese were at increased risk of being overweight or obese. Girls were also at increased risk of being overweight or obese if a biological parent was overweight.

Interpretation: Children's body weight status is associated with that of at least one of their biological parents. Having an obese parent increases the risk of overweight or obesity among children in Canada.

Keywords: Body mass index, obesity, overweight

The prevalence of overweight and obesity among children and adults has risen in Canada during the past 40 years.[1,2] The most recent estimates indicate that a third of children are overweight or obese.[3] Potential causes include genetics, family demographics, child and parent behaviour, and the larger economic and social environment in which children live.[4-6]

International studies have found a significant association between parent and child body mass index (BMI). Obesity tends to aggregate within families as a consequence of complex interactions among genetics, behaviour, and environment.[7-9] Research on BMI in families has found that parent obesity is a significant risk factor for obesity in their offspring—during childhood[10-12] and later in life.[13] The reported strength of this association varies and may reflect differences across studies in the use of measured versus self-reported height and weight to calculate BMI, and whether biological and/or non-biological parents were included in the analysis.[14]

In Canada, much of the research on childhood overweight and obesity has focussed on behavioural risk factors such as lack of physical activity,[15] poor diet,[16,17] sedentary behaviour,[15,18] screen time,[17] and inadequate hours of sleep.[15,19] Others have examined family characteristics such as parent education[20] and socioeconomic status.[21] Given that Canada's demographic, economic, and social characteristics differ from those of other countries, it is worthwhile to determine if parent-child BMI associations observed elsewhere prevail in Canada.

Using measured data for children and their biological parents collected by the Canadian Health Measures Survey, this study examines parent and child BMI in a nationally representative sample of Canadian children.

Methods

Data source

The Canadian Health Measures Survey (CHMS) is an ongoing survey designed to provide comprehensive direct health measures at the national level on the household population aged 3 to 79. Full-time members of the Canadian Forces and people living on reserves or in other Aboriginal settlements, in institutions, and in some remote regions are excluded.

The CHMS involves an in-person household interview and a subsequent visit to a mobile examination centre (MEC). The household interview gathers general demographic and socioeconomic data and detailed health, nutrition, and lifestyle information. At the MEC, direct physical measurements are taken, including height and weight. Details about the CHMS have been published elsewhere.[22]

From each household selected for the CHMS, a member is randomly chosen. If that individual is younger than 12, an older member of the same household is also chosen to participate. Although the aim of this sample selection strategy is mainly logistical (to ensure that children younger than 12 are accompanied to the MEC), it also means that data are collected from two members of the same household; in most instances, a child and one of their biological parents.

For this analysis, data from the first three CHMS cycles (2007 to 2009, 2009 to 2011, and 2012 to 2013) were pooled. Of the 3,017 selected children who were aged 6 to 11 at the time of their visit to the MEC, 1,895 (62%) also had a biological parent interviewed.

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To assess possible bias, children paired with a biological parent were compared with children paired with someone other than a biological parent. Children paired with a biological parent were more likely to be boys (54% versus 48%) and were slightly younger (average age in years 8.3 versus 9.0). However, the two groups did not differ substantially in BMI-for-age-and-sex Z-score (0.49 versus 0.48), obesity status (30% of both groups overweight or obese), average daily fruit and vegetable consumption (4.5 versus 4.6 times), average weekly hours of physical activity (11.7 versus 11.4), average daily hours of screen time (2.3 versus 2.7), average daily hours of sleep (9.7 versus 9.5), and percentage living in a lone-parent household (20% versus 19%).

The analysis was restricted to children aged 6 to 10 at the time of the MEC visit to minimize the potential effect of puberty, yielding a sample of 1,588 parent-child pairs. This was further limited to those with valid measured BMI for both parent and child, resulting in 1,563 pairs: 931 children paired with their non-pregnant biological mother (pregnant women did not have their BMI measured and were excluded from the present analysis) and 632 children paired with their biological father.

Measures

Height was measured to the nearest 0.1 centimetre using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight, to the nearest 0.1 kilogram with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada). Two parent-child pairs who could not visit the MEC had their height and weight measured at home.

BMI was calculated as measured weight in kilograms divided by measured height in metres squared (kg/m^2). For parents, three BMI categories were examined: underweight/normal weight combined (BMI $\leq$ 24.99 kg/m^2); overweight (BMI 25 kg/m^2 to $\leq$ 29.99 kg/m^2); and obese (BMI $\geq$ 30 kg/m^2).[23] For children, two BMI categories were derived from the child's BMI-for-age-and-sex Z-score, based on a set of cut-offs specified by the World Health Organization[24]: thin/normal combined ($\leq$ 1 standard deviation above the mean BMI for age and sex), and overweight/obese ($>$ 1 standard deviation above the mean BMI for age and sex). Each child had a corresponding estimate of either their biological mother's or father's measured BMI.

Covariates

In addition to child sex, child age in months, parent sex and parent age, the following parent-reported covariates were analyzed: the child's average daily fruit/vegetable consumption, weekly hours of physical activity, daily hours of screen time and daily hours of sleep; whether the child was ever breastfed; the parent's highest level of education; and whether the child lived in a lone-parent household.[22]

Child daily fruit/vegetable consumption (an indicator of diet quality[25]) was the sum of the frequency of daily consumption of 100% fruit juices, fruit, tomatoes or tomato sauce (excluding tomato paste, ketchup or pizza sauce), lettuce or green leafy salad, potatoes (including baked, boiled, mashed or in potato salad, but excluding sweet potatoes), and spinach, mustard greens or collards excluding kale. Child weekly hours of physical activity was derived from weekly hours of physical activity at school (free time and class time) and during organized and unorganized activities outside of school. Child daily hours of screen time was derived from daily hours spent watching television or videos or playing video games, plus hours on a computer (including homework and e-mailing). Parent's highest level of education was categorized as secondary school graduation or less, postsecondary below a bachelor's degree, or bachelor's degree or higher.

Statistical analysis

To account for the survey's complex sampling design, analyses were weighted using the CHMS cycle 1/cycle 2/cycle 3 combined survey weight.[26] Variance estimation (95% confidence intervals) and significance testing were done using the replicate weights generated by Statistics Canada.[27-29] The data were analyzed with SAS 9.3 and SUDAAN 11.0, using DDF = 35 (denominator degrees of freedom) in the SUDAAN procedure statements. Descriptive statistics were estimated, including means, percentages, and Pearson correlations. Mean child BMI-for-age-and-sex Z-scores were estimated across age-adjusted parent BMI (kg/m^2) deciles. A logistic regression model was used to estimate the association between categorical parent BMI and a child being overweight or obese, controlling for other risk factors, for all children and stratified by child sex. The fully adjusted model accounted for parent BMI, child sex (except in sex-stratified models), child age in years, parent sex, parent age, parent education, lone-parent status, child fruit and vegetable consumption, child physical activity, child screen time, child daily hours of sleep, whether the child was ever breastfed and a CHMS cycle indicator. Risk ratios (RRs) and their 95% confidence intervals were estimated.

In a sensitivity analysis to determine if the estimates produced by the logistic model were robust, four separate linear models were run. Two of the linear models had the child's BMI-for-age-and-sex Z-score as the outcome, and specified parent BMI as a categorical and also as a continuous variable. The other covariates were the same as in the logistic model, excluding child sex and age (which are accounted for in the Z score itself). The linear model adjusted by parent BMI (kg/m^2) was used to produce model-adjusted least squares mean child BMI Z-scores, estimated at parent BMI (kg/m^2) values of 20.3, 22.0, 23.4, 24.7, 25.9, 27.2, 28.6, 30.0, 32.8 and

39.7, which were the mean parent BMI values for each decile. The other two linear models had the child's measured BMI (kg/m^2) as the outcome; specified parent BMI as a categorical and also as a continuous variable; and included the same covariates as the logistic model. The linear model adjusted by categorical parent BMI was used to produce adjusted least squares mean estimates of child BMI (kg/m^2) according to parent BMI categories. All four linear models were stratified by child sex.

Results

Of the children in this analysis, 54% were boys, and 46% were girls (Table 1). On average, they were almost 8 years old, and 29% were overweight or obese. They ate fruit and vegetables an average of 4.5 times per day, and spent about 12 hours per week engaged in physical activity, about 2 hours per day on screen time, and just under 10 hours per day sleeping. A large majority (84%) had been breastfed, and 20% lived in a lone-parent family.

The average age of the parents in the analysis was 38. More than a third (37%) were overweight, and 25% were obese. The majority (78%) were postsecondary graduates.

The Pearson correlation coefficients (r) between the child's BMI Z-score and their parent's age-adjusted measured BMI was .24 ($p < 0.0001$). The correlation was higher for girls ($r = .35$, $p < 0.0001$) than for boys ($r = .16$, $p < 0.0001$). In general, girls' average BMI Z-score increased across the parent's age-adjusted BMI in deciles, while boys' average BMI increased mainly at the upper deciles (Figure 1).

The difference in child BMI according to their parent's BMI is further illustrated by Figure 2, which presents the percentage of children overweight or obese according to their parent's BMI category. Those whose parent was overweight or obese were more likely to be overweight or obese themselves ($p < 0.01$ for trend for boys, $p < 0.0001$ for trend for girls).

When other characteristics including child age, parent sex and age, and child behaviours such as physical activity and screen time were taken into account, the logistic regression model estimated that children with an obese parent were at increased risk of being overweight or obese (RR = 2.18; CI = 1.51 to 3.14) (Table 2). Both boys (RR = 1.79; CI = 1.13 to 2.84) and girls (RR = 3.06; CI = 2.04 to 4.60) with an obese parent were at increased risk of overweight or obesity, but only girls were at increased risk if a parent was overweight (RR = 2.32; CI = 1.43 to 3.77). These findings were corroborated by the linear regression models, regardless of whether the outcome was the child's BMI Z-score or measured BMI (kg/m^2), or whether parent BMI was specified as a continuous or categorical variable. Overall, parent BMI explained 2% of the variance in boys' BMI, and 12% of the variance in girls' BMI.

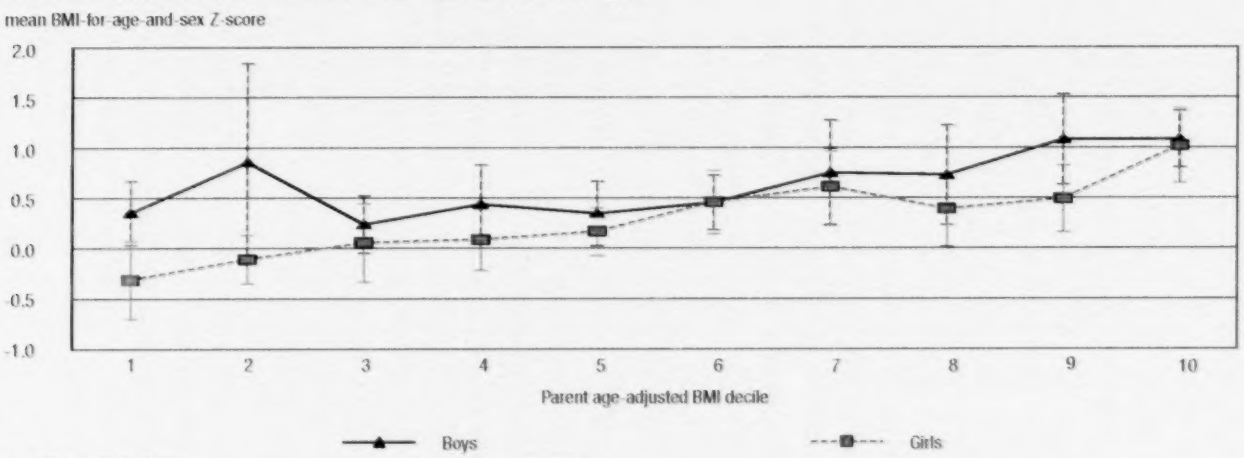
Table 3 presents the model-adjusted least squares mean child BMI (kg/m^2) according to parent BMI category. Similar to the findings from the logistic regression model, boys had a higher predicted BMI when a parent was obese, while girls had a higher predicted BMI when a parent was overweight

Table 1
Description of sample, by child and biological parent characteristics, household population, Canada excluding territories, 2007 to 2013

Characteristics	Sample size	Weighted estimate (mean or %)	95% confidence interval	
			from	to
Child				
Sex				
Male	805	54.4	51.2	57.6
Female	758	45.6	42.4	48.8
Average age (years)	1,563	7.9	7.8	8.1
Body mass index category				
Thin/Normal	1,102	71.4	67.7	74.9
Overweight/Obese	461	28.6	25.1	32.3
Fruit and vegetable consumption (times per day)	1,557	4.5	4.3	4.6
Physical activity (hours per week)	1,508	11.7	11.2	12.3
Screen time (hours per day)	1,562	2.2	2.1	2.4
Sleep (hours per day)	1,563	9.7	9.6	9.8
Breastfed as infant	1,289	84.1	81.3	86.6
Parent				
Sex				
Men	632	40.4	37.2	43.7
Women	931	59.6	56.3	62.8
Average age (years)	1,563	38.2	37.6	38.8
Body mass index category				
Normal	602	37.7	32.7	42.9
Overweight	554	36.9	33.3	40.7
Obese	407	25.4	21.5	29.8
Lone-parent household	288	20.1	16.3	24.5
Highest level of education				
Secondary school graduation or less	337	22.4	18.9	26.4
Postsecondary below bachelor's degree	664	43.3	39.1	47.5
Bachelor's degree or more	553	34.3	28.9	40.1

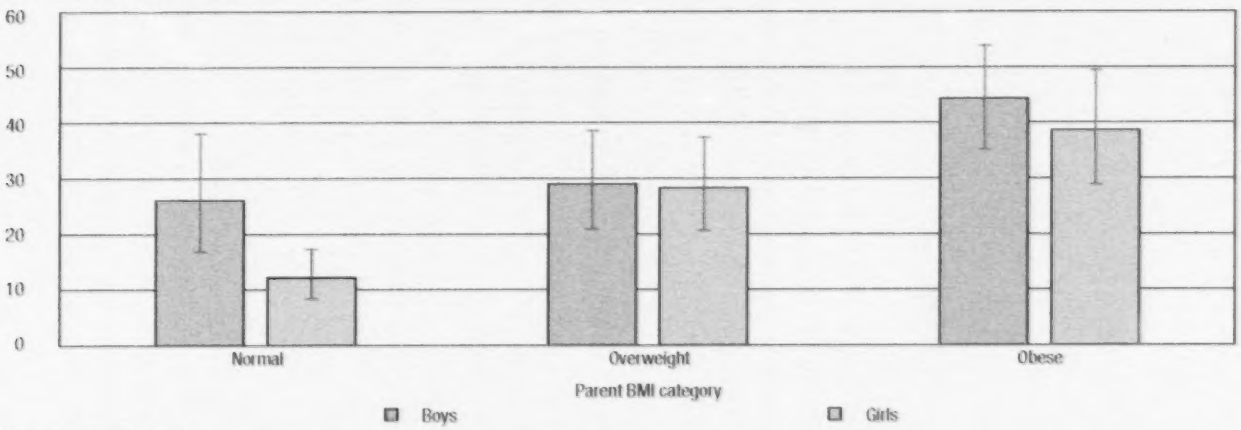
Source: 2007 to 2009, 2009 to 2011, and 2012 to 2013 Canadian Health Measures Survey, combined.

Figure 1
Mean BMI-for-age-and-sex Z-score of child, by biological parent age-adjusted body mass index (BMI) decile, household population, Canada excluding territories, 2007 to 2013



I = 95% confidence interval
Source: 2007 to 2009, 2009 to 2011, and 2012 to 2013 Canadian Health Measures Survey, combined.

Figure 2
Percentage of children overweight or obese, by biological parent body mass index (BMI) category, household population, Canada excluding territories, 2007 to 2013



I = 95% confidence interval
Source: 2007 to 2009, 2009 to 2011, and 2012 to 2013 Canadian Health Measures Survey, combined.

or obese. Figure 3 presents the model-adjusted least squares mean child BMI Z-scores for boys and girls at the mean value of parent BMI within deciles. As parent BMI increased, so did the child's BMI Z-score. Except at the two upper deciles of parent BMI, girls generally had lower predicted mean BMI Z-scores than did boys.

Discussion

This study examined associations between biological parent and child BMI in a nationally representative sample of children aged 6 to 10. Boys' and girls' BMI had a significant, positive linear relationship with their parent's BMI, but the association was stronger for girls. Boys with an obese parent were at greater risk of being overweight or obese; girls with an overweight or obese parent were at greater risk of being overweight or obese. These findings persisted regardless of other factors or the multivariable model used to examine the association.

Many studies of parent-child BMI stratified the results by parent sex rather

than by child sex.[30-32] This complicates comparisons with the present analysis, in which parent BMI could pertain to either the biological mother or father. Comparisons are further restricted by differences in the age ranges of the children in various studies, and the use of self-reported versus measured data to calculate BMI.

What is already known on this subject?

- The prevalence of overweight and obesity among children and adults has risen in Canada during the past 40 years.
- International studies have found a significant association between parent and child body mass index (BMI).
- The strength of this association varies and may reflect differences across studies in the use of measured versus self-reported height and weight to calculate BMI, and whether biological and/or non-biological parents were included in the analysis.

What does this study add?

- Using direct physical measures of height and weight from the Canadian Health Measures Survey, this study examines associations between parent and child BMI in a nationally representative sample.
- When risk factors were taken into account, a child's average BMI increased as their parent's BMI increased.
- Parent BMI explained 2% of the variance in boys' BMI and 12% of the variance in girls' BMI.
- Boys and girls with a biological parent who was obese were at increased risk of being overweight or obese; girls were also at increased risk of overweight or obesity if a biological parent was overweight.

A comparable Australian analysis based on measured data found a difference in the effect of parent BMI between girls and boys at age 9—girls had a higher average BMI if they had an overweight or obese parent, whereas among boys, a higher BMI was found only among those with an obese parent.[33] Danielzik et al.[34] reported that the odds of German children aged 5 to 7 being overweight were significantly higher for those with at least one overweight parent, and even higher if at least one parent was obese; they found little difference between boys and girls in the association.

Possible mechanisms underlying these parent-child associations include genetics,[35] fetal overnutrition,[36,37] epigenetic effects resulting from environmental exposures in the parents,[38] and family environmental factors, such as dietary practices.[39] Gender differences have been reported in both exposure and vulnerability to obesogenic environments.[40] Studies suggest that girls are more susceptible than boys to family and environmental factors associated with obesity,[41] which might help explain the stronger linear association between girls' BMI and that of their parent in this analysis. It is possible that some of the parent-daughter associations in the present study may be capturing aspects of the girls' environment that could not be directly assessed. For example, greater parental control of a child's diet has been linked to increased adiposity in girls but not boys.[40] Although the analyses adjusted for the child's reported fruit and vegetable consumption, this

Table 2
Adjusted risk ratios for association between biological parent body mass index (BMI) category and child being overweight or obese, household population, Canada excluding territories, 2007 to 2013

	Both sexes			Boys			Girls		
	Adjusted risk	95% confidence interval		Adjusted risk	95% confidence interval		Adjusted risk	95% confidence interval	
Parent BMI category	ratio	from	to	ratio	from	to	ratio	from	to
Overweight	1.49	0.99	2.25	1.09	0.59	2.00	2.32*	1.43	3.77
Obese	2.18*	1.51	3.14	1.79*	1.13	2.84	3.06*	2.04	4.60

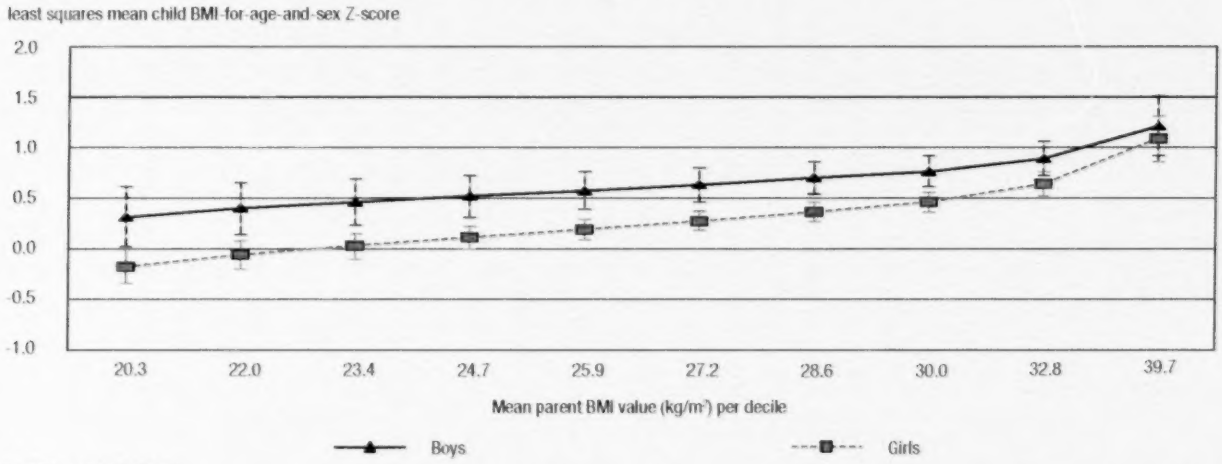
* significantly associated with child being overweight or obese ($p < 0.05$)
Note: The models were adjusted for: the child's sex (except in sex-stratified models), age in years, fruit and vegetable consumption, physical activity, screen time, hours of sleep, and whether the child was breastfed; the parent's BMI, sex, age, education, and lone-parent status; and CHMS cycle.
Source: 2007 to 2009, 2009 to 2011, and 2012 to 2013 Canadian Health Measures Survey, combined.

Table 3
Adjusted least squares mean body mass index (BMI) (kg/m²) of child, by biological parent BMI category, household population, Canada excluding territories, 2007 to 2013

	Both sexes			Boys			Girls		
	Adjusted least squares mean	95% confidence interval		Adjusted least squares mean	95% confidence interval		Adjusted least squares mean	95% confidence interval	
Parent BMI category	BMI	from	to	BMI	from	to	BMI	from	to
Normal†	16.6	16.2	17.0	17.1	16.4	17.8	16.1	15.8	16.3
Overweight	17.3*	17.0	17.7	17.5	16.9	18.1	17.1**	16.7	17.4
Obese	18.1**	17.7	18.6	18.4**	17.8	19.1	17.9**	17.4	18.4

† reference category
* significantly associated with child being overweight or obese ($p < 0.05$)
** significantly different from reference category ($p < 0.01$)
Note: The models were adjusted for: the child's sex (except in sex-stratified models), age in years, fruit and vegetable consumption, physical activity, screen time, hours of sleep, and whether the child was breastfed; the parent's BMI, sex, age, education, and lone-parent status; and CHMS cycle.
Source: 2007 to 2009, 2009 to 2011, and 2012 to 2013 Canadian Health Measures Survey, combined.

Figure 3
Adjusted least squares mean BMI-for-age-and-sex Z-score of child, by mean biological parent body mass index (BMI) value per decile, household population, Canada excluding territories, 2007 to 2013



I = 95% confidence interval
Note: The models were adjusted for: the child's age in years, fruit and vegetable consumption, physical activity, screen time, hours of sleep, and whether the child was breast fed; the parent's BMI, sex, age, education, and lone-parent status; and CHMS cycle.
Source: 2007 to 2009, 2009 to 2011, and 2012 to 2013 Canadian Health Measures Survey, combined.

is not an adequate proxy for household dietary practices. In a prospective cohort study of 7-year-olds in the United Kingdom, Reilly et al.[42] were able to control for a child's nutrition patterns at age 3. They reported a significant association between parent self-reported obesity during pregnancy and the risk of their child being obese, based on measured data, at age 7. However, no difference emerged by child sex in the association between parent and child obesity status.

Strengths and limitations

The present analysis has a number of strengths. The results are based on a nationally representative sample of children. Parent and child BMI status were derived from measured height and weight, using quality-controlled, standardized protocols. The biological relationship between the child and parent was clearly established based on detailed household composition information. Multiple statistical approaches were applied to examine associations in parent-child BMI status, while controlling for risk factors for increased child BMI. Regardless of the analytical approach, the overall findings remained robust.

At the same time, the analysis has several limitations. The CHMS is cross-sectional; consequently, the results reflect associations rather than causation. Owing to sample size restrictions, for the risk analysis, overweight and obese children were combined into a single category. Parent BMI pertained to either the biological mother or the biological father; it was not possible to examine the effects of family clustering on child BMI, nor the relative importance of mother versus father. However, one study that compared having data on one parent's BMI to having data on both parents' BMI found little effect on overall correlations between each parent and child.[43] The first three CHMS cycles were conducted during a 7-year period (2007 to 2013), and the combined non-response rate for children aged 6 to 11 was about 55%. The combined survey weight was adjusted for sampling probability and non-response, but some unknown bias might exist if children who did not participate in the CHMS differed systematically from those who did.

Conclusion

This population-based Canadian study confirmed that, similar to international research, a child's body weight status is associated with that of their biological parent. Because having an obese parent increased the risk of overweight or obesity among children, parent obesity can be considered a marker of familial risk. Further research to examine the specific determinants of obesity within families may help inform policies intended to address childhood obesity in Canada.

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